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Defects Which Reduce Quality and Yield of Oak-Hickory Stands in Southeastern Iowa

BY CHARLES M. GENAUX AND JOHN G. KUENZEL

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

FORESTRY SECTION

CENTRAL STATES FOREST EXPERIMENT STATION

FOREST SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE
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SUMMARY

Data from 753 sample trees, representative of conditions commonly encountered in forests of southeastern Iowa indicate that:

1. Volume loss from all types of defects averaged 8.5 percent of the total volume of trees in the merchantable size class, 5.2 percent of the total volume of large poles and 6.2 percent of the total volume of saplings.

2. In white oak, the most important species represented, the percentage of defective volume decreased with increasing diameter.

3. Slightly over 60 percent of the trees were partially defective from one or more causes.

4. In three out of every four defective trees the defects were evident only after felling and splitting.

5. Over 90 percent of all trees had branch stubs larger than 0.5 inch in diameter, but only 11 percent of these were defective, probably due to the fact that the majority of the sample trees were of the younger age classes.

6. Eight percent of all trees bore fire scars, and 50 percent of the scarred trees were defective. Most of the scars were found in trees of merchantable size.

7. The oldest fire scar found in one of the larger trees dissected, originated in 1847-48. Fires have occurred at irregular intervals from that date until the present time.

8. Butt rot, transmitted from the parent stump, was found to be present in the young sprout growth and less prevalent in the older sprout stands.

9. *Stereum gausapatum* was isolated more than five times as often as any other fungus. It was responsible for almost all of the basal rots of which the causal agent was identified.

10. Sixty percent of all trees bore insect injuries, although the defects caused by insects averaged less than 2 percent of the total volume for all diameter classes.

Defects Which Reduce Quality and Yield of Oak-Hickory Stands in Southeastern Iowa¹

By

CHARLES M. GENAUX AND JOHN G. KUENZEL

A sound program of land use for Iowa's remaining forests must include the application of silvicultural measures that will result in the maximum volume growth of the highest quality products obtainable in the shortest possible time. In addition to halting the further degradation of one of the state's most valuable yet sadly neglected resources, this aim can be entirely compatible with other closely related phases of management such as soil conservation, watershed protection, game production and recreation.

This bulletin discusses several prevailing types of tree defects, many of which result from past and present mistreatment of the forests. Among the agencies which reduce the quantity and quality of Iowa's timber stands are fires, grazing, improper cutting practices, insects and climatic phenomena. Several writers have dealt with different phases of this general problem as it occurs in other states, but the present investigation is the first of its kind dealing specifically with Iowa conditions.

Following preliminary steps toward the acquisition of national and state forest lands in Iowa, there has been much discussion, mostly of a conjectural nature, as to the forestry possibilities of the lands under consideration. The object of this study was to obtain factual evidence about the nature and extent of important defects in the upland oak-hickory stands of southeastern Iowa, in order to answer some of the following specific questions: How defective is the upland oak-hickory timber? What causal agents are responsible for most of the defects? What circumstances favor the incidence and development of defects? What silvicultural measures are indicated for the best development of these stands? Is it reasonable to expect to harvest a timber crop from the present stands, or are they so badly defective as to be almost worthless?

¹ This publication is the result of a cooperative undertaking between the Forestry Section of the Iowa Agricultural Experiment Station and the Central States Forest Experiment Station, Forest Service, United States Department of Agriculture, Columbus, Ohio. The work was done under Project 482 of the Iowa Agricultural Experiment Station. Charles M. Genaux, associate professor of forestry, and John G. Kuenzel, assistant silviculturist, are co-authors.

Historical accounts of forests in Iowa are meager. Estimates of the original forest area vary from less than one-eighth (42) to one-fifth (24) of the total area of the state. The most authoritative figures are believed to be those given in a typed memorandum of the Iowa State College Department of Forestry based on the Original United States Land Office Survey. These figures show that about 6,680,000 acres originally were covered with forests, and it is probable that they were subject to widespread destruction even before the advent of white settlers, as indicated by accounts of prairie fires (2)² and buffalo grazing. In general the forests have not been considered a primary resource of the state, although some pioneer writers (38) recognized their aesthetic and utilitarian values. Early agricultural reports (23) stressed the importance of forests and the uses of timber in certain sections of the state. Despite the original outlook (37)³ for expansion of the forests, a century of development discloses the total forest area reduced to about 2,358,000 acres (50). The remaining stands have been degraded by fires, grazing and destructive cutting. Impoverished soil and a declining population (15) now characterize a portion of the state for which a bright future was once predicted (37)⁴. Rehabilitation of these areas is a major item in recent state conservation planning (10).

The popular belief that the net effect of surface fires is beneficial has permitted the development of a widespread practice of annually burning woods and fields. Miller (34), however, has pointed out the fallacy of burning for improvement of woodland grazing. Furthermore, it has been advanced by Hall (17) that woods-burning for the control of crop-destroying insects is largely ineffective; in fact Graham (16) has shown that burning may actually increase the insect population of an area. In spite of educational efforts by the Forestry Department of Iowa State College through its extension service activities, woods-burning is still practiced, although the advent of organized state forestry activities is expected by MacDonald (33) to prove increasingly effective in its control.

² Page 381 "... Planting (of crops) was generally done in the edge of the timber, where most of the very earliest settlers located. . . . And still another reason for this was, that the groves afforded protection from the terrible conflagrations that occasionally swept 'accross' the 'praries.' Though they passed through the patches of timber, yet it was not with the same destructive force with which they rushed over the 'praries.' Yet by those fires much of the young timber was killed from time to time, and the forests kept thin and shrubless."

³ Pages 34-35 "... the astonishing short space of time with which the 'praries' become overgrown with thickets, when fires are kept out, show conclusively with what ease a little attention will produce a fine growth of timber. It is a matter of general observation that as the country settles, the timber increases, from the fact of the country being more fenced up, and the fires kept out."

⁴ Pages 92-93 "... the general aspect of the (Lee) county is, however, dry, handsome, moderately undulating, frequently interspersed with beautiful groves, and possessing a rich and luxuriant soil admirably adapted for agricultural pursuits, and the raising of stock."

Permanent injury to the forest site as a result of burning has been observed by Alway and Rost (1), Auten (3), Larsen (29) and others. In addition to this and the direct damage to forest trees caused by fire, there is loss traceable to the entrance of decay organisms through fire scars. This has been investigated by numerous workers, including Hartley and Boyce (18), Hedgcock (19) and Hepting (20). Fires or woodland grazing, and frequently a combination of both, result in the destruction of young trees over a period of years, until the woods assume an open, park-like appearance, as observed by Day and Den Uyl (13). In stands of this character, branches persist until heartwood forms, and dead stubs over 2.0 inches in diameter are common, favoring the entrance of decay organisms, as shown by Campbell and Moss (8). Other writers, including Graham (16) and Munns and Coville (35), have pointed out that there is increased insect activity in stands of open character.

Direct losses may result from improper cutting methods as pointed out by Kuenzel and Sutton (28). Indirect losses may occur through the transmission of butt rot to the sprout from a decaying parent stump, as described by Campbell (7) and Roth and Sleeth (39). In young sprouts where heartwood is continuous with that in the parent stump, decay is readily transmitted. In many woods of southeastern Iowa, the practice of leaving stumps 24 inches and over in height provides a ready avenue of entrance for decay into the young sprout stems. A number of studies have thrown some light on the extent and character of decay and associated losses in forests of various parts of the United States. Among these may be mentioned the study by Boyce (4) in the Douglas Fir Region, Hepting in the Mississippi Delta (20) and in the Appalachian Region (21), Kienholz and Bidwell (26) in Connecticut and many others. More particularly, the work of Kuenzel (27), Liming (30), Limstrom and Kuenzel (31) and Lorenz and Christensen (32) are of interest, since they describe conditions in neighboring states in the Central Hardwood and Ozark Regions.

The forest areas where these studies were made are part of the deciduous forest formation of the Eastern United States (41). Despite the fact that Iowa is primarily a prairie state, local conditions permit the occurrence of forests over considerable areas. The oak-hickory associates (51) constitutes the predominant forest cover type and attains near optimum development for the state in the portion of southeastern Iowa covered by this study. Of minor importance are variants of the silver maple-American elm type.

LOCATION AND DESCRIPTION OF STUDY AREAS

Study plots were established on state forest lands in Lee and Van Buren Counties, Iowa (fig. 1). Plots were selected to rep-

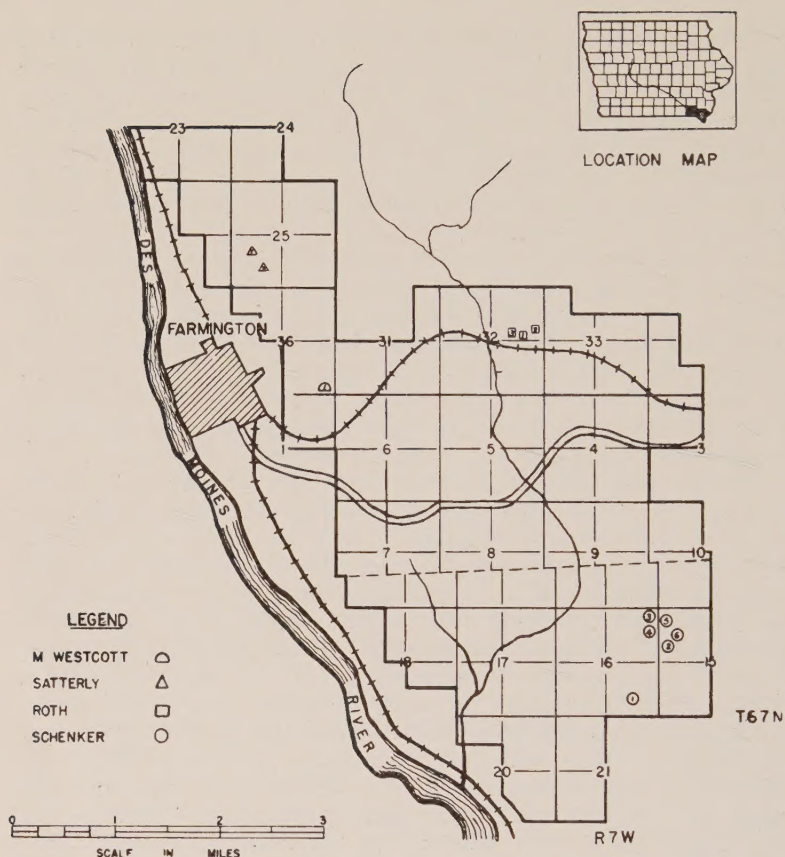


Fig. 1. Location of study plots, Iowa State Forest—Farmington Purchase Unit.

resent distinct forest cover types (44) and size classes as previously recognized (49) by Region Nine of the United States Forest Service in making acquisition surveys of these lands for the Hawkeye National Forest Purchase Unit.

Data were collected from 11 1-acre plots, five of which were in the Schenker tract, three in pole stands of the Roth tract, two in sapling stands of the Satterly tract and one in a sapling stand of the Minnie Westcott tract. Data were also taken from a 1/10-acre plot in the Schenker tract which contained some of the largest and best timber to be found on any of the purchased lands. Random or mechanical location of plots was impracticable because of the lack of uniform cover conditions. A summary of sample plot descriptions is presented in table 1.

TABLE 1. SUMMARY OF PLOT DESCRIPTIONS, BY SIZE CLASSES *a*. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Plot number and cover type <i>b</i>	All trees			Sample trees										All size classes		
	Total trees per acre <i>c</i>	Total basal area per acre	Aspect	2.6-3.5 ins. d.b.h.		3.6-7.5 ins. d.b.h.		7.6-9.5 ins. d.b.h.		9.6 ins. d.b.h.-larger					Annual radial growth last 10 years at stump	(ins.)
				No. trees	Aver- age d.b.h.	(yrs.)	No. trees	Aver- age d.b.h.	(yrs.)	No. trees	Aver- age d.b.h.	(ins.)	Aver- age d.b.h.	(yrs.)	Aver- age height	
Schenker 1 (Type 50b)	1953	107.89	NW	29	3.0	21	34	4.6	26	0	—	—	—	—	29	0.078
Schenker 2 (Type 50c)	587	82.46	N & W	16	3.0	30	30	5.4	36	4	8.4	59	14.8	89	37	0.056
Schenker 3 (Type 49c)	984	83.10	NW	13	3.1	28	24	5.2	39	4	8.2	40	11.3	69	39	0.068
Schenker 4 (Type 49c)	1727	77.53	S	29	3.0	22	33	4.5	25	2	8.2	38	—	—	30	0.082
Schenker 5 (Type 50c)	1443	95.08	S	29	3.0	27	47	4.9	31	1	7.8	34	—	—	34	0.065
Schenker 6 (Type 50)	850	118.78	N	8	3.1	34	11	5.2	60 <i>d</i>	2	8.8	80	11.7	92	66 <i>e</i>	0.059 <i>f</i>
Roth 1 (Type 50c)	541	76.22	W	7	3.0	32 <i>g</i>	32	5.6	38	3	8.5	40	—	—	37 <i>h</i>	0.072 <i>i</i>
Roth 2 (Type 49c)	462	72.96	E	9	3.1	33	26	5.3	40	4	8.7	43	15.4	95	41	0.060 <i>j</i>
Roth 3 (Type 50c)	506	82.70	E	6	3.0	28 <i>k</i>	26	5.7	38	4	8.7	38	10.8	38	6.1	0.082 <i>m</i>
Satterly 1 (Type 50b)	543	30.03	S	47	2.9	14	6	3.9	14	0	—	—	—	—	14	0.117
Satterly 2 (Type 49b)	2115	67.70	E	46	3.0	16	26	4.1	16	0	—	—	—	—	16	0.119 <i>n</i>
M. Westcott 1 (Type 50b)	1852	54.78	SW	27	3.2	18	18	3.9	21	0	—	—	11.5	81	3.7	0.100

(a) Basis: 12 plots. Total area 11.1 acres. 10 percent of stand sampled, except Schenker 6, one-tenth acre, clear-cut.
 (b) Type symbol explained in table 2.
 (c) Based on tally of all trees larger than 1.5 inches d.b.h., except Satterly 1, where all trees above 2.5 inches were tallied.

(d) Average age based on 9 trees.
 (e) Average age based on 30 trees.
 (f) Growth rate figure based on 29 trees.
 (g) Average age based on six trees.
 (h) Average age based on 41 trees.

(i) Growth rate figure based on 40 trees.
 (j) Growth rate figure based on 40 trees.
 (k) Average age based on five trees.
 (l) Average age based on 39 trees.
 (m) Growth rate figure based on 36 trees.
 (n) Growth rate figure based on 71 trees.



Fig. 2. LEFT: A 14-year-old clump of sprout growth white oak in Satterly Tract. RIGHT: Typical stand of sprout growth white oak frequently cut over for fence posts and fuel.



Fig. 3. Second growth white oak stand thinned by cuttings.

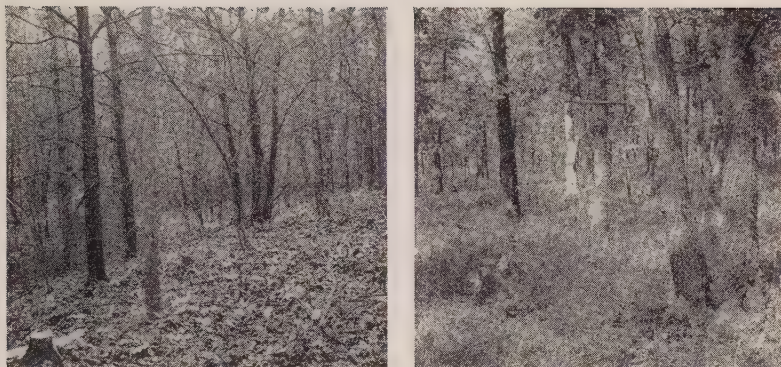


Fig. 4. LEFT: Sprout growth of white oak—black oak—red oak in Satterly plot 2, showing thrifty character of stand. RIGHT: Pole stand of white oak—black oak—red oak in Roth plot 2, showing fire scar and open character of stand promoting branch stub defects.

As in other portions of the Central Hardwood Region where agricultural land abandonment is common, timber in southeastern Iowa does not occur in extensive, unbroken stands. On the contrary, it occurs in patches of irregular size and shape, mostly in belts of varying widths along the watercourses. These tracts are interspersed with partially cleared pastureland and badly eroded fields. The topography for the most part is rolling to broken or rough.

There are only two important upland timber cover types, the white oak type (figs. 2 and 3) and the white oak—black oak—red oak type (fig. 4). As described (44) by the Committee on Forest Types of the Society of American Foresters, type 50, the white oak type, is one in which white oak predominates. The principal associates are black oak and the hickories. Type 49, the white oak—black oak—red oak type, is one in which these species predominate. Important associates here include hickories, black cherry, black walnut, American elm and hop-hornbeam. Dogwood is common in the understory. This type is generally found on the better, more moist and well-drained soils. The white oak type is without doubt much more important than the white oak—black oak—red oak type from the standpoints both of present extent and prospective commercial possibilities.

The great majority of the stands in both cover types are still in the sapling stage (49), that is stands in which the trees are not over 4.5 inches d.b.h.⁵ Pole stands (from 4.6 inches to 9.5 inches d.b.h.) are fairly well represented, but saw-timber sizes (9.6 inches d.b.h. and larger and containing at least 750

⁵ Diameter, breast high—the diameter of a tree at a height 4.5 feet above ground, commonly written d.b.h.

TABLE 2. AREAS BY COVER TYPES AND SIZE CLASSES. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Cover type and type number	Size class	Stand symbol	Area (acres)	Percent of total
1. Open grassland			2808.67	27.7
2. Cultivated			1044.19	10.3
3. Brushland			260.02	2.6
4. Bottomland hardwoods				
	Reproduction		None	—
	Saplings		153.00	1.5
	Poles		153.00	1.5
	Saw timber		169.00	1.7
5. White oak* (Type 50)				
	Reproduction		31.00	0.3
	Saplings†	50b	3518.29	34.7
	Poles	50c	247.00	2.4
	Saw timber	50	365.00	3.6
6. White oak—black oak—red oak* (Type 49)				
	Reproduction		245.00	2.4
	Saplings†	49b	—	—
	Poles	49c	670.00	6.6
	Saw timber		480.41	4.7
Total			10144.58	100.0

*The present study was confined to timber stands within the last two cover types listed.

†Sapling stands of the two upland types, white oak and white oak—black oak—red oak, are combined in the table.

board feet per acre) are comparatively lacking. Table 2 is a summary of data taken by the United States Forest Service in its acquisition survey and shows the relative importance of the different cover types and size classes in this purchase unit.

Most of the timbered lands have been more or less continuously grazed without regard to the damage resulting to the woods. Readily accessible markets for small-sized products such as mine timbers and fence posts, and requirements for fuelwood for home consumption have resulted in overcutting. These factors of grazing and heavy cutting, together with a lack of appreciation of the true value of the forest resource, have contributed to the general neglect and mismanagement of the woodlands. The majority of the tree species in the area sprout vigorously, following repeated clear-cutting for small products and culling for larger material. As a result, protected young stands are reasonably well-stocked and are thinning rapidly by natural sup-

pression. In many instances composition has deteriorated, partly because of depletion of the forest sites and partly because cutting has been confined to the more valuable white oak, thereby favoring inferior species in the new stand. The majority of the stands are understocked and characterized by the presence of a few poorly formed, defective wolf trees and younger sprout growth.

Reproduction of the commercial species is almost entirely of sprout origin, though seedlings of elm and cherry are present in some of the plots. Seedlings of oak, ash and walnut are occasionally encountered. In some cases, hop-hornbeam is invading the stands in large numbers.

No consistent differences were noted in the abundance and composition of the subordinate vegetation from plot to plot. Grass covered from 5 to 40 percent of the area of each plot. Herbaceous plants (exclusive of grass) covered from a trace to 40 percent of the area of each plot. These consisted largely of various species of ragweed (*Ambrosia*), bedstraw (*Galium*), fleabane (*Erigeron*), strawberry (*Fragaria*), cinquefoil (*Potentilla*), golden-rod (*Solidago*), violet (*Viola*) and numerous members of the mint family (*Labiatae*).

Shrubs covered from 5 to 20 percent of the area of each plot. Those present in all plots included species of sumac (*Rhus*), rose (*Rosa*) and coral-berry (*Symphoricarpos*). Almost all plots had scattered specimens or clumps of dogwood (*Cornus*), hazelnut (*Corylus*), currant (*Ribes*) and raspberry (*Rubus*), while service berry (*Amelanchier*), Virgin's bower (*Clematis*), hawthorn (*Crataegus*), St. John's-wort (*Hypericum*), Virginia creeper (*Psedera*), elderberry (*Sambucus*), green brier (*Smilax*), grape (*Vitis*) and prickly ash (*Xanthoxylum*), were found in only a few plots each.

Crown densities in the areas sampled ranged from 60 percent in Roth plot 1, to 90 percent in Satterly plots 1 and 2. The heaviest grass cover, as was to be expected, occurred in the two plots having the lowest crown densities, and comparatively little grass was found in stands that approached full stocking. Herbaceous cover (exclusive of grass) was least in a stand of average density (Schenker plot 2), while shrub cover was greatest in a similar stand (Roth plot 2).

Although the physical and chemical properties of the soil were not analyzed in this study, detailed county soil survey reports published by the Iowa Agricultural Experiment Station were available for both Lee (45) and Van Buren (46) Counties. Soil types were determined from the maps contained in these bulletins.

All plots occurred in the Southern Iowa loess soil area (6), which is the thinnest loess deposit in the state. The soil types in

this general area are usually low in fertility and limited to rolling, rough or steep topography. Three plots (Schenker 3, 4, and 5) occurred on Lindley loam, a soil derived primarily from weathering of glacial drift after most of the thin over-layer of loess had been washed away. These plots had not been burned recently. They possessed a well-formed layer of litter, very little duff, and loose, shallow, dark gray surface soil. The steep phase of Clinton silt loam was represented in only one plot, Minnie Westcott 1, which had a partial layer of litter and almost no duff. The other eight plots occurred on Marion silt loam. The loose, dark gray surface soil was covered with heavy litter in all but two instances. Two plots also had well-developed duff layers.

The tree species (47), groups and d.b.h. classes recognized in this study, together with a record of the number of trees dissected, are listed in table 3. The list may be considered representative of the species commonly encountered in the upland oak-hickory forests of southeastern Iowa. The oaks and hickories are the principal species in most stands on the uplands. Other

TABLE 3. TREE NAMES, SPECIES GROUPS, AND NUMBER OF TREES DISSECTED. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Common names	Scientific names	Number of trees dissected	Species groups
White oak	<i>Quercus alba</i> L.	427	white oak
Black oak	<i>Quercus velutina</i> La M.	88	black oak
Red oak	<i>Quercus borealis</i> Michx.	19	red oak
Shingle oak	<i>Quercus imbricaria</i> Michx.	12	other oaks
Post oak	<i>Quercus stellata</i> Wang.	11	
Shagbark hickory	<i>Hicoria ovata</i> (Mill.) Britt.	40	shagbark hickory
Mockernut hickory	<i>Hicoria alba</i> (L.) Britt	28	other hickories
Bitternut hickory	<i>Hicoria cordiformis</i> (Wang.) Britt.	12	
Other hickories	<i>Hicoria</i> spp. (undesigned species)	4	
American elm	<i>Ulmus americana</i> L.	18	elms
Red elm	<i>Ulmus fulva</i> Michx.	14	
Basswood	<i>Tilia glabra</i> Vent.	1	other desirable species
Black cherry	<i>Prunus serotina</i> Ehrh.	8	
Black walnut	<i>Juglans nigra</i> L.	8	
Cottonwood	<i>Populus deltoides</i> Marsh.	1	
Hard maple	<i>Acer saccharum</i> Marsh.	1	
White ash	<i>Fraxinus americana</i> L.	17	
Hop-hornbeam	<i>Ostrya virginiana</i> (Mill.) Koch.	44	
Total		753	non-commercial species

species listed occur only to a limited extent on the slopes and ridges. The number of trees of each species dissected is indicative of the stand composition in the sample plots.

FIELD METHODS

The methods employed in this study were essentially the same as those developed by various workers in the Division of Forest Pathology of the United States Bureau of Plant Industry and used previously by Limstrom and Kuenzel (31) in a similar study in the Missouri Ozarks.

The time and expense consequent to the felling, dissecting and detailed measurement of a large number of sample trees is a practical limitation in studies of this nature. Whereas in previous similar investigations the procedure had been to clearcut plots of different sizes, it was decided in this instance to increase the size of plots in order to improve the sample and to reduce the number of trees felled in each plot.

A preliminary selection of approximately 50 stands was made from a study of aerial photographs. Each of these stands was then examined on the ground, and 11 were found to be uniform over large enough areas to permit the establishment of 1-acre plots with suitable isolation strips. In order to obtain a sample of the larger diameter classes which occurred chiefly in scattered stands of limited area, a plot 1/10 acre in extent was established in a small stand of merchantable white oak.

A detailed description was made of each plot, and all trees above 1.5 inches d.b.h. were tallied by species and 1-inch d.b.h. classes. To avoid confusion in tallying, the 1-acre plots were marked off in strips of one-half chain in width. Every tenth tree above 2.5 inches d.b.h. was designated as a sample tree. An exception was made in the case of Schenker plot 6, the 1/10-acre plot, which was clearcut in order to make this sample as nearly as possible comparable with those from the larger plots. Every tree in this plot was thus a sample tree.

Before felling, a detailed description of each sample tree was made. Description of the standing tree involved measurement of the average d.b.h. to the nearest 0.1 inch; classification of the crown; decision as to the most probable origin of the tree; classification of the tree's general condition as good, medium or poor; notes on the nature and extent of visible defect; and finally a decision as to what disposition should be made of the tree in an administrative timber stand improvement operation. Dead branches, branch stubs and sprout stubs were counted and recorded by 1/2-inch diameter classes.

The sample trees were then felled at a conveniently low stump

height, usually 6 inches above the average ground level, and sawed into suitable lengths for handling and for making the necessary subsequent measurements. The first cut above the stump was always made at the point representing breast height on the standing tree. Average diameters inside and outside the bark were taken on the stump and at the top of each log or bolt. The length of each section and the total tree height were also taken, and the average radial growth rate for the past 10-year period was found from three equidistant radii on the stump and at breast height.

After the trees were sawed into sections, each bolt was split, and all defects were classified according to origin. Healed-over branch stubs and sprout stubs without decay were recorded but not included as defects resulting in loss of volume. The maximum diameters of decay associated with any wound were measured to the nearest inch in two directions. The maximum longitudinal spread of decay was measured to the nearest inch upward and downward from the point of origin except in the case of fire scars and butt rot, where only the upward spread above stump height was measured. The original and present widths of fire scars, in tenths of feet, were measured along the circumference of the tree on the stump.

Ages of fire scars were determined by counting the number of growth rings formed since the time of scarring. The term "fire-year" as defined by Hepting (20), was used to include the fall of a given year and the spring following, since it could not be determined in the field in which of these periods a fire occurred. Total ages of sample trees were found by making ring counts on the stump. In a few cases in which the stump sections were too defective to permit an accurate ring count, determinations of total age were omitted.

Samples of decay were taken from infected trees. These, together with careful descriptions showing the species and size of tree, the nature of the wound and the maximum spread of decay, were submitted to the Division of Forest Pathology for culturing and identification. A separate record of insect injury, including a diagram of insect tunnels in each log, was kept for each sample tree.⁶ Insect specimens were collected where possible and submitted for identification to the Division of Forest Insect Investigations of the United States Bureau of Entomology and Plant Quarantine.

Determinations of defective volumes were made and recorded separately for each defect. Those recognized included decay from fire scars, other butt rot, decay from branch stubs, in-

⁶ The outline and forms used for the study of insect damage were developed by Dr. Ralph C. Hall, formerly Assistant Entomologist at the Central States Forest Experiment Station.

sect defects and miscellaneous defects. The latter included defects from mechanical and climatic injury, sapwood decay, sweep and shake.

TOTAL AND DEFECTIVE VOLUMES

For purposes of compilation and comparison with results of similar studies elsewhere in this region, trees were separated into the following arbitrary size classes:

Saplings	2.6—3.5 inches d.b.h.
Small poles	3.6—7.5 inches d.b.h.
Large poles	7.6—9.5 inches d.b.h.
Merchantable	9.6 inches d.b.h. and larger

The total and defective volumes for all species and size classes are summarized in table 4. These data are based on the 12 plots sampled, with all volumes shown in total merchantable cubic feet, excluding stump. Total volume was determined by planimetry from plotted graphs drawn to scale for each sample tree. Defective volume in cubic feet was determined from individual measurements made in accordance with standard practice of the United States Forest Service (48). Trees in the small pole class show a greater percentage of defective volume than those in the sapling class. Conclusions regarding a similar relation in the large pole and merchantable size classes cannot be drawn from the limited data for larger trees. The importance of insect injury decreases in larger trees. Miscellaneous defects arising from mechanical and climatic injuries, sapwood decay, sweep and shake, cause moderate loss in volume in all size classes.

Owing to maltreatment many of the stands are understocked. As a result the trees develop an excessive number of branch stubs and knots. Most of the branch stubs, however, are less than 2.0 inches in diameter and expose insufficient heartwood to create a decay hazard. The percentage of defect associated with branch stubs in large pole and merchantable size classes is low in comparison with conditions in upland stands of adjacent states (27, 31).

Considering that a large proportion of all trees in the present stands of southeastern Iowa originated as stump sprouts, it is interesting that with the exception of post oak, shingle oak and red oak, defect caused by basal rot transmitted from the parent stump was low in all size classes. This condition may be peculiar to Iowa. It is accounted for in part by the fact that the sprouts are generally of low origin (39) and by the common practice of removing merchantable materials at a low rotation age before an excessive amount of basal decay appears. Even so, the com-

TABLE 4. VOLUME AND PERCENT OF DEFECT IN UPLAND HARDWOODS.* IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Size classes and Species groups†	Tree basis (number)	Gross volume (cubic feet)	Defective volume (cubic feet)	Total defect (percent)	Decay from fire scars (percent)	Other butt rot (percent)	Branch stub (percent)	Insects (percent)	Miscel- laneous‡ (percent)
2.6-3.5 inches d.b.h.									
White oak	158	77.73	5.13	6.6	0.6	1.6	0.1	0.9	3.4
Black oak	44	22.04	1.03	4.7	Tr.‡	0.4	Tr.	1.3	3.0
Red oak	2	1.02	0.02	2.0				2.0	
Other oaks	1	0.72	0.07	9.7		4.1			5.6
Shagbark hickory	18	9.30	0.81	8.7	4.2		0.4	4.0	0.1
Other hickories	16	8.77	0.75	8.6			0.1	8.5	
Elms	12	5.70	0.45	7.9		Tr.	4.3	1.8	1.8
Other desirable species	6	3.11							
Non-commercial species	9	4.99	0.08	1.6	Tr.			1.6	
All species	266	133.38	8.34	6.3	0.6	1.0	0.3	1.7	2.7
3.6-7.5 inches d.b.h.									
White oak	189	327.77	15.06	4.6	1.1	1.5	0.3	0.8	0.9
Black oak	35	61.64	6.88	11.2	5.9	2.8	0.5	0.9	1.1
Red oak	11	24.50	4.54	18.5		1.1	1.1	8.1	8.2
Other oaks	18	43.05	2.71	6.4	5.6	0.2	0.1	0.5	
Shagbark hickory	20	38.85	3.60	9.5	2.3	Tr.		3.3	3.3
Other hickories	11	26.37	3.26	12.7			7.5	3.3	1.9
Elms	8	14.39	0.99	6.8					6.8
Other desirable species	15	36.77	1.96	5.3	2.9	0.2	1.4	0.4	0.4
Non-commercial species	1	1.25	0.02	1.6				1.6	
All species	308	572.69	39.11	6.8	2.0	1.2	0.7	1.4	1.5

TABLE 4—(Continued)

7.6 - 9.5 inches d.b.h.										
12	White oak	72.16	2.20	3.0	0.3	1.2	1.3	0.5		
5	Black oak	39.15	0.73	1.9				1.6		
2	Red oak	11.82	1.44	12.2		5.8	4.7	1.7		
1	Other oaks	8.96	0.20	2.2				0.4		1.8
2	Shagbark hickory	10.55	1.29	12.2			3.1	1.0		
2	Other hickories	1.84	1.84	100.0						8.1
1	Elms	6.21	0.14	2.3			2.3			100.0
1	Other desirable species	2.79	0.17	6.1	0.4		3.2			2.5
Non-commercial species										
26	All species	153.48	8.01	5.2	0.1	1.0	1.3	0.9		1.9
9.6 inches and over d.b.h.										
16	White oak	233.19	3.62	1.6	0.5		0.8	0.2		0.1
3	Black oak	57.58	23.92	41.5	38.9		1.5	1.1		
2	Red oak	24.16	0.04	0.2				0.2		
	Other oaks									
	Shagbark hickory									
1	Other hickories	10.82	1.00	9.2	0.2		2.9	6.1		
1	Elms	10.34								
Non-commercial species										
23	All species	336.09	28.58	8.5	7.0		0.9	0.6		Tr.

*Basis: 12 plots; 11.1 acres; 10 percent of stand sampled; 623 trees over 2.5 inches d.b.h. dissected; 1195 cubic feet merchantable volume. All volume derived from plotted individual tree measurements merchantable cubic feet, to a top diameter limit of 2.5 inches inside bark, based on the accepted standard for fence posts and mine timbers in southeastern Iowa.

†For composition of species groups see table 3.

‡Includes defects due to mechanical and climatic injury, sapwood decay, sweep and shake.

#Tr. - trace, less than 0.1 percent defect.

plete absence of this type of decay in a majority of the sprouts is not fully explained.

RELATIVE IMPORTANCE OF VISIBLE AND INVISIBLE DEFECTS

Previous studies (27, 31) have pointed out that although it was possible to determine with a reasonable degree of accuracy the presence of decay in standing trees, it was not possible to estimate correctly the amount of such decay. Table 5 gives the percentages of total trees with visible and invisible defects. External observations frequently showed apparent defects which proved upon dissection to cause no volume loss. Such cases were omitted from the table. Since each sample tree was carefully examined to note visible evidences of decay, the results are indicative of the inaccuracies which may occur in an ocular estimate of the amount of defect in standing timber.

The figures in the percent columns represent the percentage of the total number of trees defective from the various causes.

TABLE 5. PERCENTAGE OF TOTAL TREES WITH VISIBLE AND INVISIBLE DEFECTS*. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Species groups†	Tree basis	Not defective	Types of defect								Total		
			Fire scars		Branch stubs		Butt rot		Insect‡		Visible	Invisible	
			Visible	Invisible	Visible	Invisible	Visible	Invisible	Visible	Invisible			
	(no.)		(percent of total trees)										
White oak	419	35.8	2.4	2.4	1.4	6.9	2.9	6.2	3.6	46.3	10.3	61.8	
Black oak	87	35.6	2.3	8.0		2.3	4.6	2.3	9.2	47.1	16.3	59.8	
Red oak	19	10.5	10.5			5.3	5.3	10.5		68.4	15.8	84.2	
Other oaks	22	27.3	18.2	22.7		4.5	4.5		4.5	27.3	27.3	54.5	
Shagbark hickory	40	27.5	17.5	2.5		2.5	2.5		12.5	52.5	32.5	57.5	
Other hickories	44	31.8			6.8	6.8			4.5	52.3	11.4	59.1	
Elms	31	61.2				12.9	3.2	6.5	12.9	6.5	16.1	25.8	
Other desirable species	36	50.0	2.8		11.1	16.7	2.8		11.1	19.4	27.8	36.1	
Non-commercial species	44	65.9	2.3	2.3	2.3	2.3			6.8	18.1	11.4	22.7	
Total	742	37.7	3.6	3.2	1.9	6.5	2.8	4.3	5.7	42.5	14.0	56.5	

*Basis: 12 plots; 742 trees.

†Includes miscellaneous defects due to mechanical and climatic injury and sapwood decay, which were occasionally associated with insect injury.

‡For composition of species groups see table 3.

Thus 10.3 percent of the white oak trees in all size classes were defective from visible types of injuries, while 61.8 percent of all white oaks bore invisible defects. The sum of 10.3 and 61.8 does not equal the total percentage of all white oaks defective, since a single tree frequently had visible defects of one kind and invisible defects of another. This percentage may be calculated by simply subtracting the percentage not defective from 100. In this particular case, the percentage of white oak trees defective would be 35.8 from 100, or 64.2 percent.

The total percentages of all trees having visible and invisible defects were 14.0 and 56.5 respectively. Wide variations occurred in the visible and invisible percentages for various types of defect. For fire scars the percentage was low in both classes. In the case of branch stubs, visible defects were insignificant and invisible defects were considerably more important, indicating that most of this type of defect was associated with closed or healed-over branch stubs. In basal decay from causes other than fire, invisible defect was slightly greater than visible defect. The relation of visible to invisible insect defects was in the ratio of 1 to 7. Insect injury was common in all species.

BRANCH STUB DEFECTS

A predominance of trees with excessive branch stubs may be expected in uneven-aged stands of open character. Under such conditions complete natural pruning is not readily accomplished (figs. 5 and 6). As disclosed in table 6, more than 90 percent

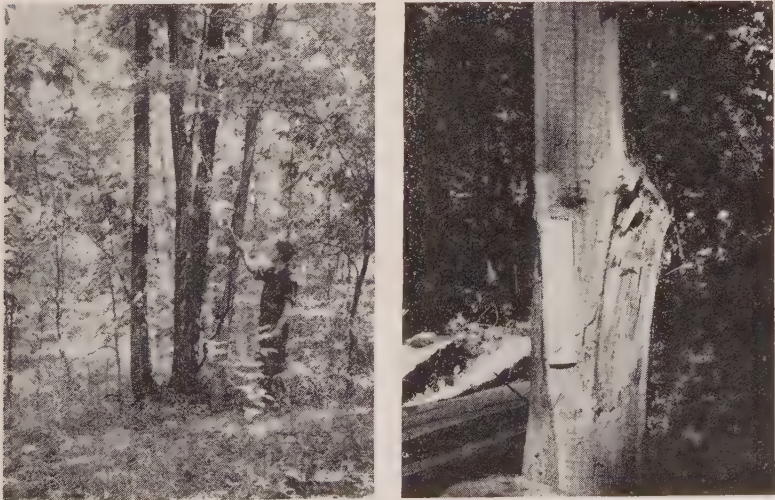


Fig. 5. LEFT: Typical dead branch on a red oak sprout. RIGHT: Decay associated with a branch stub in white oak.



Fig. 6. LEFT: Open grown white oak sprout, 30 years old, showing a branch stub at 8 feet and the lowest live branch at 16 feet. Roth Tract. RIGHT: Much forest land in southeastern Iowa consists of second growth timber tracts interspersed with partially cleared pasture land.

of all trees examined were found to have branch stubs larger than 0.5 inch in diameter. Branch stubs less than 0.5 inch in diameter were disregarded. Closed branch stubs were not differentiated into size classes because most of them were below 1.5 inches. The prevalence of trees having closed branch stubs

TABLE 6. OCCURRENCE OF BRANCH STUB DECAY IN TREES WITH BRANCH STUBS 0.5 INCH AND OVER IN DIAMETER. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Species groups*	Tree basis	Trees with branch stubs		Trees with branch stub decay	
	(number)	(number)	(percent)	(number)	(percent)
White oak	427	411	96.3	39	9.1
Black oak	88	57	64.8	6	6.8
Red oak	19	19	100.0	4	21.1
Other oaks	23	22	95.7	1	4.3
Shagbark hickory	40	33	82.5	2	5.0
Other hickories	44	42	95.5	6	13.6
Elms	32	27	84.4	5	15.6
Other desirable species	36	35	97.2	8	22.2
Non-commercial species	44	41	93.2	2	4.5
Total	753	687	91.2	73	9.7

*For composition of species groups see table 3.

TABLE 7. AVERAGE SPREAD OF DECAY FROM OPEN AND CLOSED BRANCH STUBS IN UPLAND HARDWOODS. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Species groups*	Open				Closed		Total	
	Under 2 inches in diameter		2 inches and over in diameter		0.5 inch and over in diameter			
	Tree basis	Average decay spread	Tree basis	Average decay spread	Tree basis	Average decay spread	Tree basis	Average decay spread
	(no.)	(ins.)	(no.)	(ins.)	(no.)	(ins.)	(no.)	(ins.)
White oak	6	24	2	31	27	14	35	16
Black oak	0	0	0	0	6	17	6	17
Red oak	0	0	0	0	4	43	4	43
Other oaks	0	0	0	0	1	12	1	12
Shagbark hickory	0	0	0	0	1	15	1	15
Other hickories	3	50	0	0	3	29	6	40
Elms	2	14	1	8	3	10	6	11
Other desirable species	0	0	0	0	6	12	6	12
Non-commercial species	0	0	0	0	2	8	2	8
Total	11	29	3	23	53	17	67	19

*For composition of species groups see table 3.

was striking. Open branch stubs were classified as under 2 inches, and 2 inches and over, in diameter, in order to make data comparable with those of similar studies elsewhere in the region. Only three trees were found to have open branch stubs over 2 inches, and all of these were defective.

Branch stubs were regarded as defective only in those cases where decay extended well beyond the branch trace. The occurrence of branch stub decay also is shown in table 6. Only 9.7 percent of all trees examined had branch stubs which were defective, probably because most of the trees were of the younger age classes.

The average spread of decay, shown in table 7, indicates the relative susceptibility by species to branch stub defects (figs. 7 and 8). Red oak and "other hickories" exhibited the maximum decay spread from this type of wound. In a few cases, branch stub decay was coextensive with decay from other sources. The omission of data for these trees in the calculation of the average spread of decay accounts for the discrepancy between the total tree basis in table 7 and the total trees with branch stub decay in table 6.



Fig. 7. TOP: Sections of dissectioned black walnut trees, showing: 1. Defective open branch stub having insect tunnels. 2. Sound open branch stub. 3. Defective closed branch stub (note light colored decay in heartwood). 4. Defective closed branch stub (note light colored decay in heartwood). 5. Healed-over branch stub. 6. Sound partly healed branch stub. BOTTOM: Sections of dissectioned oak trees, showing: 7. Sound open branch stub in red oak. 8. Insect tunnel in a closed branch stub, also a sound healed branch stub in red oak. 9. Defective open branch stub in white oak (note light colored decayed area). 10 and 11. Sound open branch stubs in shingle oak.

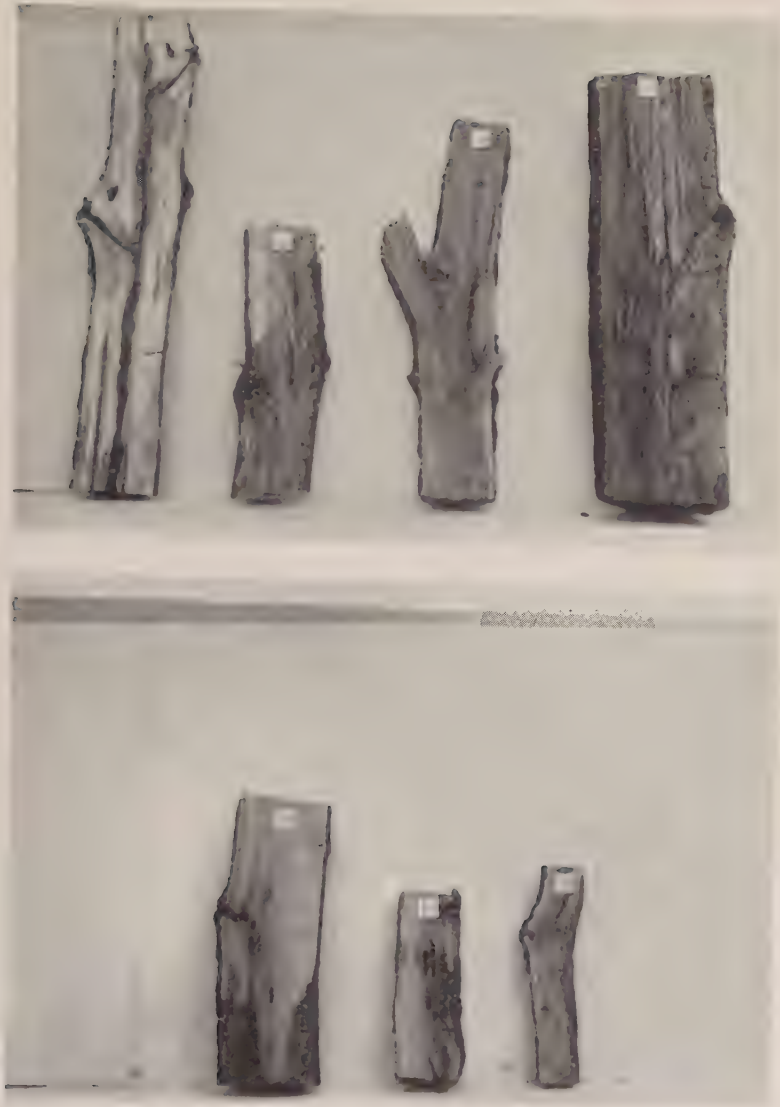


Fig. 8. TOP: Sections of dissected trees, showing: 12. Defective open branch stubs in shagbark hickory (note insect tunnel through center of larger stub). 13. Defective closed branch stub in shagbark hickory. 14. Sound dead branch in red elm. 15. Defective small open branch stub in red elm, showing insect tunnel. BOTTOM: Sections of dissected trees, showing: 16. Insect tunnels associated with small branch stubs in red oak. 17. Insect tunnels in red oak. 18. Insect tunnel associated with branch stub in white oak.

DEFECTS DUE TO FIRE

Careful examination of literature (10, 24, 33) which might be expected to shed some light on the importance of forest fires in Iowa fails to provide quantitative information regarding either the acreage burned or the extent of damage caused. Here, as elsewhere, the damage caused by fires may be divided into two broad classes, direct and indirect. The first (36), resulting when trees are killed and wood volume is destroyed, did not come under intensive scrutiny in this investigation. Furthermore, it was not possible in this instance to appraise such forms of indirect damage as the reduction in growth rate caused by the burning of soil organic matter, or the decrease in wood quality resulting from opening up the stands.

One form of indirect damage, namely heart-rot resulting from the entrance of decay organisms through fire wounds, can readily be measured on felled trees. This is often a source of major loss, as shown by Hepting (20) and other writers (27, 31). In single, standing trees, the evidence of past fire may be quite apparent in the form of an open scar, with or without decay, or it may be healed over and hidden. These latter closed fire scars may also be accompanied by decay, or they may have healed over so rapidly that decay never started or has since been arrested. In this study, trees with closed fire scars unaccompanied by decay were not designated as defective where the fire wounds caused no measureable loss in volume. In sample trees with open fire scars or those having closed fire scars accompanied by decay (figs. 9, 10 and 11), the dimensions of defective portions were carefully measured.

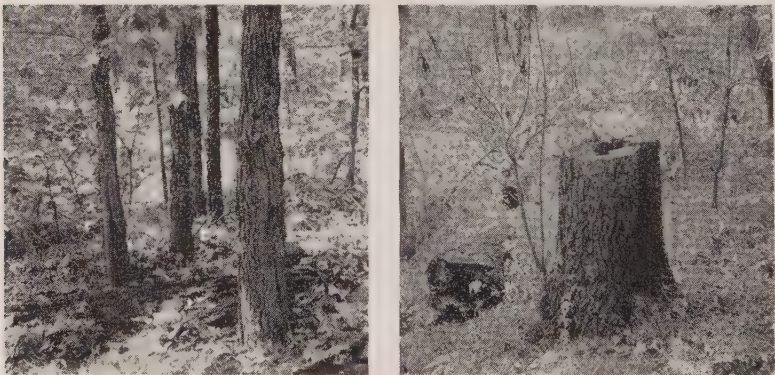


Fig. 9. LEFT: A group of fire-scarred white oaks showing partially healed-over scars. RIGHT: Over half of the merchantable volume in this black oak was cull as a result of decay entering a fire scar made 35 years ago.



Fig. 10. LEFT: Sixteen-year-old black oak sprout, showing fire scar healed over 5 years after the burn. Note the high, charred stump which provided fuel and resulted in the scarring of all attached sprouts. RIGHT: The same 16-year-old black oak sprout, showing fire scar decay in an opened section of one of the sprouts 5 years after scarring.

Table 8 shows the extent of fire scarring and associated decay, by species, for the 753 trees that were dissected. As indicated by the table, only 8.0 percent of all trees examined had fire scars. In the majority of cases the wounds had healed. Only 2.3 percent of all examined trees were found to have open fire wounds. This is low as compared with findings of similar studies



Fig. 11. LEFT: A group of fire-scarred trees, Roth Tract. Note the clump of black oak sprouts, scarred on inner side, as a result of fire in the old stump. RIGHT: Fire scar decay in a black oak sprout, burned 10 years ago and again scarred by a surface fire in 1936. Note partly healed scar and light patches of decay.

TABLE 8. EXTENT OF FIRE SCARRING AND RESULTANT DECAY IN UPLAND HARDWOODS. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Species groups*	Tree basis	Open fire scars		Closed fire scars		Total		Defective trees†		
		Tree basis		Tree basis		Tree basis		Total trees		Scarred trees
	(no.)	(no.)	(%)	(no.)	(%)	(no.)	(%)	(no.)	(%)	(%)
White oak	427	4	0.9	21	4.9	25	5.9	11	2.6	44.0
Black oak	88	2	2.3	10	11.4	12	13.6	5	5.7	41.7
Red oak	19	2	10.5	1	5.3	3	15.8	2	10.5	66.7
Other oaks	23	2	8.7	6	26.1	8	34.8	5	21.7	62.5
Shagbark hickory	40	6	15.0	3	7.5	9	22.5	6	15.0	66.7
Other hickories	44	1	2.3	0	0	1	2.3	0	0	0
Elms	32	0	0	0	0	0	0	0	0	0
Other desirable species	36	0	0	1	2.8	1	2.8	1	2.8	100.0
Non-commercial species	44	0	0	1	2.3	1	2.3	0	0	0
Total	753	17	2.3	43	5.7	60	8.0	30	4.0	50.0

*For composition of species groups see table 3.

†Defective trees are those having decay associated with the fire scars.

in other parts of the Central States Region. It is of interest that exactly 50.0 percent of the dissected fire-scarred trees were defective. The incidence of decay, moreover, was slightly greater in trees with closed fire scars, than in those with open scars.

Data presented in table 4 indicate that the total defect due to fire is relatively unimportant except in the merchantable size class. The evidence, however, is admittedly incomplete, since decay following fire may already have resulted in the death of

TABLE 9. COMPARATIVE FIRE HISTORY, BY PERIODS, OF FOUR TRACTS IN UPLAND HARDWOODS. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Tract	1931 - 1937		1912 - 1931		1847 - 1912		Total	
	Fires	Scars	Fires	Scars	Fires	Scars	Fires	Scars
	(no.)	(no.)	(no.)	(no.)	(no.)	(no.)	(no.)	(no.)
Schenker	1	1	4	5	7	7	12	13
Roth	0	0	26	39	4	4	30	43
Satterly	1	3	5	6	0	0	6	9
Minnie Westcott	0	0	1	1	0	0	1	1
Total	2	4	36	51	11	11	49	66

many injured trees in the smaller sizes. These obviously could not be taken into account in this study.

Fire history data, when arranged by consecutive years, fell into three well-defined frequency periods. These were used as the basis for table 9 to show the comparative fire history of the four tracts studied. The record for the period 1847 to 1912 is incomplete, since much of the evidence of early fires has disappeared. The infrequency of fires in spite of a prolonged drouth during the last few years demonstrates the effectiveness of the Civilian Conservation Corps in this area. The proximity of the railroad which passed closer to the Roth tract than to any other, may account for the fact that more fires occurred on the three Roth plots than on all other plots combined.

BUTT ROT OTHER THAN THAT FOLLOWING FIRE INJURY

As noted by Joranson (25) and Larsen (29), the majority



Fig. 12. Sprout stand of white oak, black oak and hickory. High stumps and dead sprout stubs, permitting entrance of decay, are common. Minnie Westcott Tract.

of the trees examined were of sprout origin. The amount of butt decay was found to be less than might be expected in stands of this character. There are several explanations, one of which agrees with findings of Roth and Sleeth (39, 40) that small stump diameter and low sprout origin favor a low percentage of basal decay. A large portion of the present sprout stands has developed from stumps less than 8 inches in diameter, following the cutting of trees for fence posts and other small products. In some of the small trees examined, decay was in-



Fig. 13. LEFT: A 32-year-old white oak sprout, in a stand similar to that in fig. 12, showing callous growth around cavity formed by decay of parent stump. RIGHT: Section of white oak sprout, showing heartwood decay transmitted from the parent stump. Decay was inactive after 32 years.

active before heartwood formation had progressed into the lower part of the bole. In many trees basal swellings indicated a partial or complete healing over of the parent stump or stool.

As shown in table 10, the percentage of defect attributed to butt rot other than that following fire was found to be very low in all species. The diminishing importance of this type of defect with increased diameter is illustrated in the case of white oak, where the total volume defective because of butt rot is of some importance in sapling and small pole sizes and insignificant in the large pole and merchantable sizes (figs. 12 and 13).

MISCELLANEOUS DEFECTS

Miscellaneous defects are rather important in the stands where observations were made and cause considerable loss of volume in small size classes (table 4). The most common defects of this type include mechanical injury such as logging damage; climatic injury due to glaze or sleet storms, frost cracks and wind breakage together with accompanying decay. Sapwood decay, sweep and shake are also present. Many of these defects are not readily discerned in standing trees and as in the case of insect injury, appear only after the tree is felled (table 5).

FUNGI RESPONSIBLE FOR DECAY

The relative importance of fungi collected during this study is indicated in table 11. A total of 166 decay specimens taken from 137 sample trees yielded only 55 isolations in pure culture. The most outstanding fact revealed by this table is that most of the basal decay is directly attributable to *Stereum gausapatum*. This finding corroborates the conclusions of Davidson (11) and Lorenz and Christensen (32), that *Stereum gausapatum* is one of the most important butt-rotting organisms in

TABLE 10. EXTENT OF BUTT ROT OTHER THAN THAT FOLLOWING FIRE.*
IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Species groups† and d.b.h. classes	Tree basis	Trees with butt rot		Volume of defect due to butt rot	
(inches)	(number)	(number)	(percent)	(cubic feet)‡	(percent)
White oak					
2.6-3.5	158	13	8.2	1.29	1.6
3.6-7.5	189	20	10.6	4.97	1.5
7.6-9.5	12	3	25.0	0.88	1.2
9.6- +	16	0	0	0	0
Black oak					
2.6-3.5	44	2	4.5	0.07	0.4
3.6-7.5	35	4	11.4	1.70	2.8
7.6-9.5	5	0	0	0	0
9.6- +					
Red oak					
2.6-3.5	2	0	0	0	0
3.6-7.5	11	2	18.2	0.27	1.1
7.6-9.5	2	1	50.0	0.68	5.8
9.6- +	3	0	0	0	0
Other oaks					
2.6-3.5	1	1	100.0	0.03	4.1
3.6-7.5	18	1	5.6	0.07	0.2
7.6-9.5	1	0	0	0	0
9.6- +	2	0	0	0	0
Shagbark hickory					
2.6-3.5	18	0	0	0	0
3.6-7.5	20	1	5.0	0.01	Tr.#
7.6-9.5	2	0	0	0	0
9.6- +					
Other hickories					
2.6-3.5	16	0	0	0	0
3.6-7.5	11	0	0	0	0
7.6-9.5	2	0	0	0	0
9.6- +	1	0	0	0	0
Elms					
2.6-3.5	12	1	8.3	0.01	Tr.
3.6-7.5	8	0	0	0	0
7.6-9.5	1	0	0	0	0
9.6- +	1	0	0	0	0
Other desirable species					
2.6-3.5	6	0	0	0	0
3.6-7.5	15	1	6.7	0.07	0.2
7.6-9.5	1	0	0	0	0
9.6- +					
Non-commercial species					
2.6-3.5	9	0	0	0	0
3.6-7.5	1	0	0	0	0
7.6-9.5					
9.6- +					
All species					
2.6-3.5	266	17	6.4	1.40	1.0
3.6-7.5	308	29	9.4	7.09	1.2
7.6-9.5	26	4	15.4	1.56	1.0
9.6- +	23	0	0	0	0

*Basis 12 plots; 623 trees.

†For composition of species groups see table 3.

‡Volume in cubic feet for merchantable portion of tree as defined in footnote, table 4.

#Tr. - Trace, less than 0.1 percent defect.

TABLE 11. FREQUENCY OF FUNGUS ISOLATIONS, BY TYPES OF DECAY, FOR ALL TREE SPECIES. IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Fungi	Butt rot*	Branch stub	Other†
<i>Armillaria mellea</i> (Vahl.)Quel.	1		
<i>Auricularia auricula-judae</i> L.		4	
<i>Hydnum erinaceus</i> (Bull.)Fr.		1	1
<i>Nummularia</i> sp.			1
<i>Peniophora pubera</i> (Fr.)Sacc.		1	
<i>Pholiota adiposa</i> (Pers.)Fr.			1
<i>Polyporus compactus</i> Overh.			1
<i>Polyporus fissilis</i> Berk. & Curt.		1	
<i>Polyporus obtusus</i> Berk.			1
<i>Polyporus versicolor</i> (L.)Fr.		1	
<i>Poria andersonii</i> (E. and E.) Neuman		4	1
<i>Pseudovalsa longipes</i> (Tul.)Sacc.‡	1		
<i>Schizophyllum commune</i> Fr.		1	1
<i>Stereum frustulosum</i> (Pers.)Fr.	1		
<i>Stereum gausapatum</i> Fr.	23	1	2
<i>Stereum rameale</i> Schw.		2	
<i>Strumella coryneoidea</i> Sacc. and Wint.			3
Unidentified fungus		1	
All fungi	26	17	12

*Includes decay associated with fire scars and other butt rot.

†Includes decay associated with mechanical and climatic injury, sapwood decay and shake.

‡Not a wood-destroying fungus; usually associated with cankers.

the Central States. Roth and Sleeth (39, 40) found it to cause most of the decay originating in the parent stump in sprout oak stands in the Appalachian and Allegheny Regions. None of these men, however, did any field work in Iowa. It is of further interest that Kuenzel (27) and Limstrom and Kuenzel (31) did not find this fungus to be of major importance in similar studies in the adjacent states of Illinois and Missouri, respectively. Davidson, Campbell and Blaisdell (12) have recently summarized the available information on *Stereum gausapatum* in the oaks, indicating that it may cause more top rot than butt rot in stands of seedling origin, where no parent stump exists to provide entrance into the young tree.

Table 11 must not be interpreted as indicative of the relative importance of the various kinds of defects. Isolation and identification was successful in 25 out of a total of 45 cases of butt rot, in only 17 out of a total of 50 cases of branch stub decay and only 12 out of 70 cases of other defects, including fire scars and insect injuries. More isolations were made from white oak than from all other species combined, but this was naturally to be expected because of the preponderance of white oak among the dissected trees. *Strumella coryneoidea* was limited to decayed sapwood of white oak, which indicates that it may have been a factor in causing the death of the affected trees. Although this fungus has been collected from numerous widely separated parts of the United States (5), the writers have found no reference in pertinent literature to its having previously been found in Iowa. *Poria andersonii* appeared to be

the most important fungus causing branch stub decay, especially in oak. The fungus *Auricularia auricula-judae* was isolated only from decayed heartwood of three living black walnut trees but has not definitely been proved to be the causal agent of such decay. The other species of wood-destroying fungi, reported as more or less widely distributed and sometimes important in other regions (5, 22), occurred infrequently, and their role in Iowa is not yet established. Meanwhile, Davidson and others (12) have shown the relative importance of 48 species of oak fungi including several species collected in Iowa. It is of interest that no important host preferences appeared in Davidson's results. While the present study resulted in only one isolation of *Nummularia* from decayed sapwood of red oak, the characteristic encrusted lesions produced by this fungus were observed on numerous dead specimens of red oak, black oak, shingle oak and hickory. It was also found on some trees which were not entirely dead, leading to the suspicion that the organism is at least a contributory cause of the death of many oaks, particularly of the black oak group.

DEFECTS CAUSED BY INSECTS

The insect injury commonly encountered in Iowa stands is not of a character readily discerned by casual observation. Sometimes a small emergence hole in the bark, a tunnel in a branch stub or in small trees the presence of a wet, discolored patch on the bark is the only external evidence of insect activity. Occasionally a fire scar or other defect has insect galleries associated with decayed or sound wood. More frequently the evidence of insect attack is not apparent until the tree is cut into sections and split. Then small irregular tunnels are found to extend from a few inches to a few feet upward or downward from a scar or wound.

Detailed examinations for insect attack were made of 510 sample trees, representing all the trees that were dissected except those on Schenker plots 1 and 2. Most of the insect tunnels were of limited extent and did not result in the loss of appreciable volume. However, the major part of the insect activity occurred in sound wood (fig. 8), even though entrance to the tree was gained through wounds. In only a few cases was insect injury associated with extensive decay. Insect infestations were found to occur in 306 trees, or 60 percent of those examined. Of the infested trees, 83 percent contained the work of primary wood borers as determined by the presence of emergence holes, indicating that these insects were capable of attacking and completing development in living trees without the presence of scars or branch stubs for oviposition. The work of secondary borers was found in 106, or 34.6 percent of the in-

TABLE 12. EXTENT OF INSECT INJURY AS INDICATED BY THE NUMBER OF INFESTED TREES.* IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Species groups†	Tree basis	Trees with insect infestations	
	(number)	(number)	(percent)
White oak	299	192	64
Black oak	77	41	53
Red oak	11	10	91
Other oaks	23	9	39
Shagbark hickory	35	21	60
Other hickories	20	16	80
Elms	15	1	7
Other desirable species	21	11	52
Non-commercial species	9	5	56
All species by d.b.h. classes (inches)			
2.6-3.5	218	116	53
3.6-7.5	250	158	63
7.6-9.5	20	14	70
9.6- +	22	18	82
Total	510	306	60

*Basis: 10 plots; 510 trees.

†For composition of species groups see table 3.

festated trees. With the exception of two instances in which the secondary borers evidently entered through fire scars, the attacks of these insects occurred through branch stub or sprout stub wounds.

Table 12 shows the distribution of insect attacks by species and d.b.h. classes. On the basis of this table, it appears that red oak is somewhat more susceptible to insect attack than the other species studied, while the elms appear to be considerably less so. It is significant that 64 percent of the 299 white oak trees examined had been injured by insects. A further fact, not shown in the table, is that 56 percent of all the white oaks contained the work of primary wood borers. When data for all species are combined it is evident that the percentage of trees with insect infestations increases directly with increasing diameter.

It is probable that the full import of the insect problem in the area studied, cannot be learned from table 12, nor even from table 4, which shows the percent of defective volume resulting from insect injury. It is quite possible that the most serious effects of insect activity are to be found in complex relationships among insects, fungi and trees. These relationships, not yet fully explored, may account for much of the unexplained tree mortality.

TABLE 13. CLASSIFIED LIST OF INSECT LARVAE AND ADULTS COLLECTED FROM ALL TREE SPECIES.* IOWA STATE FOREST—FARMINGTON PURCHASE UNIT.

Insects	Infestations
Larvae	(number)
<i>Coleoptera</i> :	
<i>Buprestidae</i> -	
<i>Dicerca</i> sp.	1
<i>Cerambycidae</i> -	
<i>Goes pulverulentus</i> (Hald.)	2
<i>Goes tigrinus</i> (DeG.)	4
(the white oak borer)	
<i>Goes</i> sp.	1
<i>Parandra brunnea</i> (Fab.)	1
(the pole borer)	
<i>Diptera</i> :	
<i>Cecidomyiidae</i> -	
<i>Psilicephala</i> sp.	1
<i>Tenebrionidae</i> -	
<i>Strongylium tenuicolle</i> (Say.)	6
<i>Xylopinus</i> sp.	1
<i>Lepidoptera</i> :	
<i>Cossidae</i> -	
<i>Prionoxystus robiniae</i> (Peck)	1
(carpeniter worm)	
Adults	
<i>Orthoptera</i> :	
<i>Blattidae</i> -	
<i>Cryptocercus punctulatus</i> (Scud.)	1
(wood cockroach)	
<i>Parcoblatta</i> sp.	1
<i>Hymenoptera</i> :	
<i>Formicidae</i> -	
<i>Camponotus pennsylvanicus</i> (DeG.)	1
(carpeniter ant)	
Total identifications	21

[*Basis: 10 plots; 510 trees.

Table 13 shows a classified list of the insect larvae and adults collected during the course of the study and identified by the Division of Forest Insect Investigations. The most important are members of the genera *Goes*, *Parandra* and *Prionoxystus*. The high percentage of trees bearing primary insect attacks seems to point to the genus *Goes* as the most important, although the number of collections was so small that there is a possibility that other important forms were missed entirely. *Goes tigrinus* (the white oak borer) in particular, is reported by Craighead (9) and Graham (16) to be common in hickory, walnut and oak in the southern and eastern United States. It is distinctly primary. Members of the genera *Parandra* and *Prionoxystus* appear to do most of their damage to injured or weakened hardwood trees, according to Doane and others (14).

Of the remaining larvae identified, the genus *Dicerca* contains species which may damage deciduous trees (9). The members of

the family *Cecidomyiidae* are the gall gnats, considered relatively unimportant in deciduous forests; and those of *Tenebrionidae* are mostly scavengers, as pointed out by Doane and others (14). Some economic importance is indicated by Snyder (43) for unnamed species of *Strongylium*.

Of the adults, the wood cockroaches are of no economic importance. Carpenter ants may be important, but the damage caused by them in standing hardwood trees is usually slight, according to Graham (16). These insects attack living trees only through decayed areas.

CONCLUSIONS AND RECOMMENDATIONS

The percentage of defective volume found in upland hardwoods of southeastern Iowa is generally less than that found in nearby states. However, from 5 to 8 percent of the total merchantable volume is defective, and this represents an economic loss of some consequence. The principal agents responsible for reduction of volume and quality are fungi and insects, but many of the circumstances which permit the development of fungus and insect injury are man-caused and therefore largely preventable. Most important are conditions arising from forest fires, grazing and improper cutting practices.

Much improvement can be brought about by reasonable care and the application of simple well-advised principles of forest management. Not only can the volume of defect be materially reduced, but the quality of products grown can be greatly enhanced. At the same time, if well-stocked stands of vigorous trees are maintained, a much higher rate of volume growth is possible. The most urgent present need is for adequate protection from grazing and fire. This means fencing stock out of areas that are to be used for forestry purposes. It requires an awakening of public consciousness to the damage caused by fires. It means alertness to discover and put out fires which accidentally start and abandonment of the practice of deliberate annual burning.

Cutting practices also can be greatly improved. Almost every area presents a new problem requiring specific local recommendations. Suggestion of a few broad principles is offered as a guide to woods practice, however, because these fundamentals are so generally ignored by forest owners in southeastern Iowa. Trees to be left should be carefully selected since they are the basis of the next crop. Healthy, well-formed trees of commercially valuable species should be favored. They should be protected during and after the cutting operation and should be grown in closed stands to stimulate early natural pruning. Cutting to supply farm needs for fuel and fence posts should,

when possible, utilize crooked, poorly formed and defective trees. This practice will provide more space for the straight, fast-growing, desirable trees and allow them to develop additional clear volume of high quality and greater market value. It is wise to remove from the stand trees showing external evidence of decay as well as those with severe insect or other injuries. Thinnings in stands of pole size and larger trees, should take out entire sprout clumps in order to eliminate the possibility of transmission of heartwood decay from a stump to the remaining companion sprouts. Stumps should be cut low not only to permit maximum utilization but also to promote the development of new sprouts from points near the ground.

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